Comparing Seven Planting Tools for Container-Grown Longleaf Pine Seedlings

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Abstract

We compared seven tools for planting container-grown longleaf pine seedlings in fine sandy loam in Louisiana and in fine sand in Alabama. The tools were (1) JIM-GEM® KBC dibble bar, (2) JIM-GEM® OST Dibble Bar, (3) Terra Tech Styro 8 Dibble Stick, (4) container seedling tube dibble, (5) hoedad, (6) auger, and (7) shovel. Significant differences in variances between the two sites 15 months after planting negated comparing tools between sites. When tools were compared at individual sites, significant root collar diameter and shoot dry weight differences were reported in Louisiana and root distribution differences were reported in Alabama. Root mass, root/shoot ratio, and number of first-order lateral roots egressed from the root plug did not differ significantly among planting tools at either site.

Introduction

Interest in restoring longleaf pine (*Pinus palustris* Mill.) across its native range in the Southeastern United States has partly focused on increasing its acreage from 1.4 to 3.2 million ha (3.4 to 8.0 million ac) by 2024 (America's Longleaf 2009). The Longleaf Partnership Council estimated that in 2012 1.7 million ha (4.2 million ac) of forest were dominated by longleaf pine (Gaines 2012). The States within the longleaf range have projected that there will be 2.4 million ha (6.0 million ac) of longleaf pine range wide by 2027 (Gaines 2012). To achieve either of these outcomes will require forest, pasture, and croplands to be reforested or converted to longleaf pine, primarily via planting seedlings.

Up to 69 million longleaf pine seedlings are produced annually, of which 70 to 90 percent are grown in containers (Barnard and Mayfield 2009, McNabb and Enebak 2008, South and others 2005). With the preference for container stock, research continues across the longleaf pine range to examine the effects of size and type of container on longleaf pine seedling quality, both in the nursery and after outplanting (e.g., Barnett and McGilvray 2002; Haywood and others 2012; South and others 2005; Sword Sayer and others 2009, 2011). One emphasis of this research has been to improve the distribution of fibrous roots within the container cavity and thereby the outplanted seedling's root architecture for years to come (Barnett and McGilvray 2002; Sword Sayer and others 2009, 2011). How important is the planting tool, however, in determining shoot and root development of planted seedlings?

Several kinds of planting tools have been used in container studies. South and others (2005) used augers to plant seedlings while Sword Sayer and others (2009) used solid, round dibbles or punches although, in both cases, the research focused on container type and size. Jones and Alm (1989) and Johnson and others (1998) evaluated planting tools, but their emphasis was on planting errors, seedling survival, and height growth rather than on root-system development. Leduc and others (2011) found root structure differences when comparing two tools on a single site. Bolstered by these results, we expanded to comparisons of seven planting tools used at two distinct locations—a fine sandy loam in Louisiana and a fine sand in Alabama. The objectives were to determine if planting tool affects subsequent shoot and root development of longleaf pine seedlings.

Methods

The U.S. Department of Agriculture (USDA), Forest Service Southern Region, Atlanta, GA, supplied the longleaf pine seeds that came from a Florida source. Seeds were sown in mid-May 2009 in Copperblock™ Styroblocks (Beaver Plastics model number 112/105, 3.6 cm [1.4 in.] diameter with 14.8 cm [5.8 in.] depth). Using protocols adapted from Barnett and McGilvray (1997, 2000), USDA Forest Service personnel at the Alexandria Forestry Center, Pineville, LA, grew the seedlings for 28 weeks. Briefly, the growing medium was a 1:2 (volume:volume) mixture of peat moss and vermiculite amended with Scott's Osmocote® 14-14-14 slow-release fertilizer at a rate of 3.6 kg/m^3 (6.1 lb/yd^3). Between mid-July and late August 2009, personnel applied a 0.05 percent (weight/volume) solution of Peter's Professional® 20-20-20 water-soluble fertilizer three times to root plug saturation. In mid-August, personnel drenched seedlings with a 0.12 percent solution of Scott's Banrot® broad-spectrum fungicide at 2.50 L/m^2 (0.06 gal/ft^2), followed by 1.25 L/m^2 (0.03 gal/ft^2) water to rinse chemical residue off the needles. Seedlings were grown for 4 weeks under ambient light in a greenhouse before being moved outdoors and grown until outplanting.

Seedlings were outplanted in December 2009 on the Palustris Experimental Forest (31.162° N., 92.668° W.) in southwest Rapides Parish, LA, and the Escambia Experimental Forest (31.027° N., 87.041° W.) in southwest Escambia County, AL. At the Palustris site, the soil is a Malbis fine sandy loam (fine-loamy, siliceous, subactive, thermic Plinthic Paleudults), and the soil at the Escambia site is a Troup fine sand (loamy, kaolinitic, thermic Grossarenic Kandiudults).

Before seedlings were planted, a 15- by 20-m (49- by 66-ft) area was rotary mowed. Single tree plots were established in a completely randomized experimental design laid out as 10 rows of 14 trees each at 1- by 1-m (3.3- by 3.3-ft) spacing. Twenty container seedlings were replicates for each treatment that were randomly planted with each of the seven tools for a total of 140 seedlings. The seven planting tools were (1) JIM-GEM® KBC Dibble Bar, (2) JIM-GEM® OST Dibble Bar, (3) Terra Tech Styro 8 Dibble Stick (dibble stick), (4) container seedling tube dibble (tube dibble), (5) hoedad, (6) auger with a 4.45-cm (1.75-in.) inside-bit diameter, and (7) shovel (figure 1). The shovel was used to carefully plant each seedling as one would for landscaping purposes and was meant to be the good-as-planting-can-be check treatment (figure 2). The hoedad was considered the most difficult tool to use and required the most time to plant seedlings on these relatively flat sites, and the auger and shovel required more time than the KBC dibble bar, OST dibble bar, dibble stick, and tube dibble to plant seedlings. The KBC dibble bar, OST dibble bar, dibble stick, and tube dibble were similarly easy to use and required about the same amount of time to plant seedlings. Cost of tools varied among the following tools: KBC dibble bar ($35.96), OST dibble bar ($35.50), dibble stick ($81.50), tube dibble ($62.65), hoedad ($92.40), auger ($158.00), and shovel ($61.50).

On the Palustris site, growing season (March through November, 2010) precipitation totaled 74.3 cm (29.3 in), which was 34.0 cm (13.4 in) less than the 50-year average (National Climatic Data Center 2011). Average daily temperature was 23.0 °C (73.4 °F) for the growing season, which was great-er than the monthly 50-year average from April through November. Similarly, on the Escambia site, growing season precipitation totaled 82.3 cm (32.4 in), which was 26.3 cm (10.4 in) less than the 50-year average. Average daily temp-erature was 21.8 °C (71.3 °F) for the growing season, which was greater than the monthly 50-year average from April through November. Based on monthly Palmer Drought Severity Index values, the Palustris site was in mild-to-severe drought conditions April through November and the Escambia site was in mild-to-moderate drought conditions June through November.

In March 2011, 15 months after planting, all longleaf pine seedlings were excavated at a 15-cm (6-in) radius from the stem base and effort was made to extract the roots to their deepest point. Excavated seedlings were washed before measurements were taken. Root-collar diameter (RCD) was measured with calipers. Seedlings were separated into

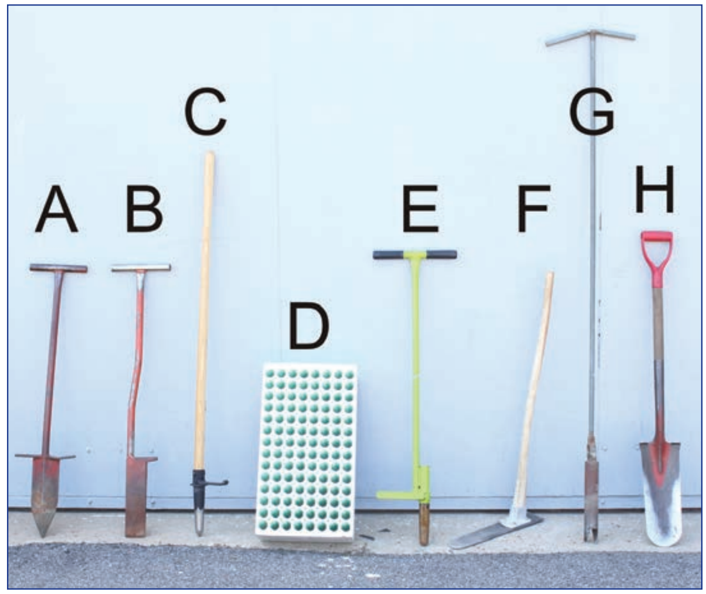

Figure 1. The seven planting tools and type of Styroblock used in this study were (A) JIM-GEM® KBC dibble bar, (B) JIM-GEM® OST dibble bar, (C) Terra Tech Styro 8 dibble stick, (D) Copperblock™ Styroblock, (E) container seedling tube dibble, (F) hoedad, (G) auger, and (H) shovel. (Photo by Daniel J. Leduc, USDA Forest Service, Southern Research Station, Alexandria Forestry Center, 2012)

Figure 2. Photograph illustrating the careful planting of a seedling in the good-as-planting-can-be check treatment. (Photo by Daniel J. Leduc, USDA Forest Service, Southern Research Station, Alexandria Forestry Center, 2009)

above- and below-ground portions using the root collar as the dividing point. After drying to equilibrium at 70 °C (158 °F) in a forced-air oven, dry weights of the above- and below-ground portions were determined. The root/shoot ratio of each seedling was calculated.

To determine root-system architecture, the number of first-order lateral roots (FOLRs) that had egressed from the root plug was counted. FOLRs are the primary lateral roots with diameters greater than 1.00 mm (0.04 in.) at 5.00 mm (0.20 in.) from the taproot. To do the counting, each seedling's root system was placed on a diagram divided into quadrants with a solid black central circle that delineated the outside wall of the root plug before outplanting (Leduc and others 2011), and each egressed FOLR was counted. In addition, quadrants with at least one end of an egressed FOLR were counted as described by Leduc and others (2011).

Differences among tools, sites, and their interaction were evaluated using PROC GLM (SAS Institute Inc. 1985); and the residuals were then tested for departures from normality using PROC UNIVARIATE. If the distribution of the residuals was found to be significantly different from normal by the Kolmogorov-Smirnov test, then differences in tools were tested using PROC NPAR1WAY. After the first series of tests, it was determined that significant differences in growth magnitude existed between the two sites (figure 3) as well as unequal variance among treatment groups. Therefore, response variables from each location were analyzed separately with the exception of mortality, which had similar variances for both sites and was therefore analyzed across both sites to maintain adequate degrees of freedom.

Results and Discussion

Of the 280 longleaf pine seedlings planted for both locations, 37 died—likely because of the drier-than-normal and warmer-than-normal growing season in 2010. No significant differences were noted in survival between locations (data not shown).

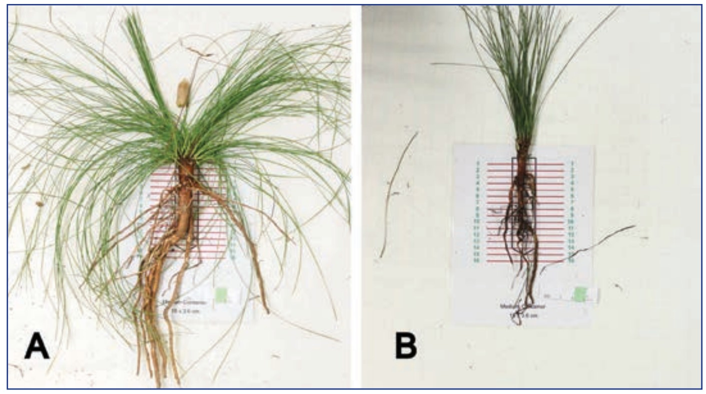

Figure 3. Two average-size longleaf pine seedlings on the Escambia (A) and Palustris (B) sites; seedlings were grown in Copperblock™ Styroblocks and planted using an OST dibble bar. (Photo by Daniel J. Leduc, USDA Forest Service, Southern Research Station, Alexandria Forestry Center, 2011)

The largest differences in seedling development were not among tools but between locations. The seedlings planted on the Escambia site grew much larger than those planted on the Palustris site (figure 3). Some of the size differences might be attributed to less severe drought conditions on the Escambia, but more likely, it was due to better site conditions than the Palustris site based on soil type and level of vegetation competition.

The planting tools had few significant differences in seedling growth. On the Palustris site, only RCD and shoot dry weight differed significantly among tools (table 1). For both variables, seedlings planted using the OST dibble bar were largest although not significantly larger than those planted using the dibble stick, hoedad, or shovel.

On the Escambia site, only the distribution of roots into quadrants differed significantly among tools (table 2). Seedlings planted using the dibble stick, tube dibble, and shovel had the best root distribution, while those planted using the KBC dibble bar, OST dibble bar, and auger had the poorest root distribution. In addition, although not significant, the root/shoot ratio was greater for seedlings planted using the KBC and OST dibble bars than for those planted using the dibble stick.

Table 1. Mean growth variables for longleaf pine seedlings planted using seven different tools on the Palustris Experimental Forest (Malbis fine sandy loam). For each variable, columnar means followed by the same letter are not significantly different based on Duncan's Multiple Range Test.

Tools	RCD (mm)	Shoot dry weight (g)	Root dry weight (g)	Root/shoot ratio	Number of quadrants with egressed root ends	Number of egressed FOLR
KBC dibble bar	14.7bc	8.7ab	8.8a	0.93a	1.2a	7.9a
OST dibble bar	16.6a	10.1a	9.4a	0.94a	1.5a	8.1a
Dibble stick	15.6 ab	8.3ab	9.0a	1.09a	1.4a	8.4a
Tube dibble	13.7c	6.5b	7.0a	1.07a	1.2a	6.9a
Hoedad	14.9abc	8.3ab	8.7a	1.06a	1.8a	7.7a
Auger	14.0bc	7.3b	7.2a	0.97a	1.4a	7.2a
Shovel	15.5ab	10.1a	9.5a	0.95a	1.4a	8.3a

FOLR = first-order lateral roots. RCD = root collar diameter.

Table 2. Mean growth variables for longleaf pine seedlings planted using seven different tools on the Escambia Experimental Forest (Troup fine sand). For each variable, columnar means followed by the same letter are not significantly different based on Duncan's Multiple Range Test.

Tools	RCD (mm)	Shoot dry weight (g)	Root dry weight (g)	Root/shoot ratio	Number of quadrants with egressed root ends	Number of egressed FOLR
KBC dibble bar	20.9a	28.0a	33.2a	1.19a	1.6c	7.8a
OST dibble bar	19.4a	23.9a	29.7a	1.20a	1.6c	7.7a
Dibble stick	21.5a	33.9a	34.4a	1.00a	2.0abc	10.0a
Tube dibble	21.0a	30.9a	32.8a	1.04a	2.7a	9.8a
Hoedad	20.4a	33.8a	37.9a	1.13a	1.8bc	9.1a
Auger	19.7a	26.9a	28.9a	1.06a	1.6c	8.4a
Shovel	20.6a	30.2a	32.4a	1.06a	2.6ab	9.7a

FOLR = first-order lateral roots. RCD = root collar diameter.

Contradictory outcomes between the two sites occurred for several other variables. For example, planting using an OST dibble bar or shovel on the Palustris site resulted in the greatest shoot dry weight, while on the Escambia site, no significant shoot dry weight differences existed among planting tools and seedlings planted using an OST dibble bar were ranked last for shoot dry weight (tables 1 and 2). On the Palustris site, planting seedlings using a tube dibble resulted in significantly smaller RCD than planting using several other tools and the seedlings were ranked last in RCD, shoot dry weight, and root dry weight. On the Escambia site, RCD, shoot, and root dry weights of seedlings planted using a tube dibble were not significantly different compared with the other planting tools.

Barnett (1978) found that loblolly pine (*P. taeda* L.) seedlings survived better in a heavy silt loam when the holes were cored rather than punched. He suggested that tools such as the dibble stick compact the soil and possibly reduce the ability of the root system to penetrate the sides of the hole. In contrast, he reported better survival for seedlings planted in punched holes rather than cored holes on a sandy loam soil. Similarly, survival and height growth of lodgepole pine (*P. contorta* Douglas ex Louden) in compacted clay loam was best when a soil core was removed before planting using a tool similar to the tube dibble (Bohning 1981). Seedling survival in noncompacted soils (bulk density < 1.6 g/cm^3 [100.0 lb/ft^3]), however, was as good when planting in punched holes compared with cored holes. Based on USDA Natural Resources Conservation Service (2012) soil surveys, the bulk density at one-third bar-soil moisture for the Escambia site was 1.54 g/cm^3 (96.00 lb/ft^3) and for the Palustris site was 1.51g/cm^3 (94.00 lb/ft^3). These low bulk densities at both sites help to explain why planting tools had little influence on survival or other parameters in this study.

Leduc and others (2011) determined that a solid round dibble (similar to the dibble stick) was superior to a tube dibble in terms of the number of FOLRs and number of quadrants with roots. In our current study, however, the statistical differences in root architecture among the dibble stick, tube dibble, and auger were not sufficient on either site to conclude that planting seedlings using one of these three tools would result in better root-system architecture than the other tools (tables 1 and 2).

Conclusions

In Sword Sayer and others (2009), the development of FOLRs and root-system architecture were considered important in predicting seedling access to surface-soil resources, growth, and the future stability of saplings and trees in high, sustained winds. For practical purposes, the type of planting tool in the current study did not affect root-system architecture on either site, at least for the first 15 months after planting. We concluded that none of the planting tools in general were superior to the others and that, as concluded by Adams and Patterson (2004), how well seedlings are handled and the care taken to plant them may be more important than the tool used. In addition, cost differences and the expected useful life of the tools might help determine which tool to use.

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